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these measurements have been made in detail for many different wave-lengths and with the very high degree of precision necessary to observe the fluctuations of contrast of brightness from time to time. The measurements extended beyond the visible spectrum both towards the ultra-violet and towards the infra-red, and showed a striking change of distribution along the sun's diameter, depending on the difference of wave-length.

10. *Solar Theory*.—These solar radiation measurements, including those of the solar constant which have led to a value of the sun's effective temperature, those on the distribution of light over the sun's disk, and those on the transmission of the terrestrial atmosphere considered in conjunction with the known results of others on the details of the solar spectrum, have led to a theory of the sharp boundary of the sun and other things relating thereto which appears more and more to gain acceptance.

REPLANTATION OF ENTIRE LIMBS WITHOUT SUTURE OF VESSELS*

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Read before the Academy, April 24, 1922

The experiments were undertaken with view to determining the amount and duration of the swelling which would result from the division of all the vessels and lymphatics of a limb, our interest in the subject arising from the desire to obtain experimental support of my contention that permanent swelling of the arm following operations upon the axilla is probably invariably due to infection, an infection often so slight as to escape the observation of the surgeon. It is almost a daily experience of active surgeons to see swollen arms as result of radical operations for cancer of the breast. The swelling is frequently so great as to cause suffering and disability from the weight of the arm, and occasionally patients have consented to amputation of the entire limb for the condition which surgeons have been powerless to relieve. The ordinary swelling is universally attributed to the removal of the axillary lymphatics and veins, and some surgeons have advocated operations less thorough, believing that their results as regards the swelling of the arm have been better when the axilla was less meticulously cleaned.

Almost from the beginning of our radical operations for cancer of the breast I have been impressed with the fact that infection, however slight, was likely to be followed by more pronounced swelling of the arm and that the largest arms were noted as a rule in cases in which the inflammatory reaction and the axillary induration were greatest. We assumed, naturally,

that the excessive swelling must be due to the blocking of lymphatics and possibly veins uninjured by the knife.

About thirteen years ago a modification of the operative procedure was made, particularly in the manner of closing the wound, and thereafter, to our surprise, swollen arms became almost a thing of the past. I say "to our surprise," for the modifications in the operation were made primarily merely in the hope of securing greater freedom of motion at the shoulder joint.

Now inasmuch as the destruction of lymphatics and veins was identically the same in the modified as in the original procedure, we concluded that the most thorough excision of the axillary contents could not alone produce swelling of the arm, and that whatever the predisposing cause might be, the ultimate factor in the production of the swelling must be something which had been eliminated in the newer procedure.

It is a common observation that a moderately swollen arm may after an interval of a year or more become markedly increased in size. This augmentation is generally and quite properly attributed to a recurrence of the disease. Occasionally, but rarely, I have observed an arm that for a year or more after the operation had maintained approximately its normal size swell quite acutely. The swelling might follow closely upon constitutional symptoms—nausea, malaise, chill and fever—and be coincident with a slight or even bright blush of the skin of the shoulder, arm, and perhaps chest and forearm.

For example, in May, 1920, a patient upon whom I had performed a radical operation for mammary cancer in November, 1916, consulted me in regard to an acute swelling of the arm on the operated side. The arm had maintained its normal size prior to an "attack" in February, 1920, in the course of her convalescence from influenza. This attack as she terms it was ushered in by nausea, a chill and high fever. The arm promptly began to swell and there appeared "redness in streaks" from the shoulder to the wrist; in a few days the redness was diffuse and the swelling of the arm had become distressingly great; the hand, she said, resembled a "boxing glove," and pressure on it with the fingers produced "deep pits." In eight or ten days the redness had vanished and the swelling was decreasing. During the three months prior to this her second admission to the Johns Hopkins Hospital, there had been a less rapid reduction in the size of the affected (left) limb, which about the middle of the arm measured in circumference 9.5 cm. more than the other, and at the middle of the forearm, 3.5 cm. more. No glands were palpable above the clavicle, and there seemed to be no abnormal fullness or resistance below it. In the skin at the outer-upper edge of the grafted area there was recurrence of the carcinoma—two nodules, not ulcerated, one about the size of a filbert, the other smaller than a split pea.

The immediate cause of the swelling was undoubtedly the local infection, for during the three years and three months prior to this and subsequent to the operation there had been nothing to indicate a blocking by recurrent disease of the lymph channels.

Eight days after the second admission (June 1, 1920), the patient was operated upon by Dr. Mont Reid, our resident surgeon. The second and a part of the third portion of the axillary vein were found to be completely occluded by the new growth, which was continuous with the larger of the two cancerous nodules in the skin. The axillary vein and the recurrent growth were excised in one piece, the disease being given a wide berth. On examination of the specimen it seemed quite clear that the vein had been invaded from without, and had surely been occluded long before the attack of infection. After this operation the swelling rapidly subsided and in the course of two months the arm had almost regained its normal dimensions.

In this case, as in a number of others observed in our clinic, the occlusion of the axillary vein plus the excision of the axillary lymphatics was not followed by any swelling of the arm.

I have under observation several patients who each year following the operation have had one or two or more attacks of the kind described, each attack being followed by an increase in the size of the arm.

Only four days ago I received an announcement of the death of a patient whose story subsequent to an operation for cancer of the breast sustains the view that swelling of the arm may be due to infection even when local and general signs of inflammation are wanting. This patient was operated upon by me five years ago. About nine months after the operation she consulted me in regard to a rather acute but inconsiderable swelling of the arm on the affected side, which theretofore had not been swollen. She could not recall having had constitutional symptoms and was quite sure there had been no inflammatory redness of the arm coincident with first appearance of its enlargement. From the time of this interview until her death, four years and three months later, there had been no augmentation of the swelling. She died of carcinomatous metastases in the bones. There was no recurrence of the disease either locally or in lymphatic glands which could have affected the circulation of the arm. Hence the swelling which occurred nine months after the operation could not have been due to the blocking of lymphatics by cancer.

Operations upon the glands of the groin may be followed by elephantiasis of the scrotum. One patient in this category was operated upon by me about forty years ago. During all this period he has each year had mild local attacks of an infection resembling erysipelas and with each attack a slight, transient, increase in the elephantiasis.

Now if redness or even a faint blushing of the arm always accompanied

the advent of the swelling which occurs after an interval the discovery would undoubtedly have been made long ago of the relationship of infection to the swelling of the arm. But an infection quite negative in external manifestations other than swelling may I believe exist and suffice to produce the further blocking which in my opinion is essential to the production of the swelling.

In a word, then, I have thought it unlikely that the excision of the axillary contents, lymphatics and veins, could alone be responsible for the swelling of the arm which is observed after the radical operation for cancer of the breast in non-recurrent cases.**

Thirty-five years ago (in 1887) I successfully transplanted the hind leg of a dog from one side to the other, leaving however the main artery intact for a few days—until union between the muscles and other divided tissues had taken place. And in more recent times (1907) Carrel, with the aid of his vascular suture, made the remarkable discovery that the leg from one dog can be transplanted to another.

The operative work in the current experiments has been done by my assistants, Dr. F. L. Reichert, Dr. Mont Reid and Dr. C. Y. Bidgood. The arterial and lymphatic injections, the preparation of the specimens, the X-ray studies are all the work of Dr. Reichert.

At the outset of our experiments I had it in mind merely to determine the amount and duration of the swelling which would follow the division of all the lymphatics and veins of the thigh. At the primary operations all the soft tissues except the femoral artery and vein and the sciatic nerve were divided and immediately reunited by suture. On the second day after the replantation the femoral vein was tied in two dogs; in one of these gangrene promptly followed the ligation. Then on the fourth day after replantation the experiment of ligating the femoral vein was twice made; gangrene resulted in one of these dogs. Ligations on the 5th, 6th, 7th, 9th, and 11th days and at later periods have not been followed by gangrene; and if performed as late as the 9th day, by little or no increase in the size of the limb. Replantation and simultaneous ligation of the femoral vein was invariably followed by gangrene—6 cases.

In one case the femoral artery and vein were ligated simultaneously with the replanting—gangrene followed. Both femoral vessels may be safely ligated on the 6th day, and probably earlier.

In one instance the replantation was successful notwithstanding the fact that the femoral artery and vein had become totally obliterated by ligation of these vessels 7 months previously.

As the possibility of an anastomotic circulation by way of the bone and sciatic nerve naturally occurred to us, Dr. Reid, in one dog, divided these structures as well as the others. The replantation was successful.

To Dr. Reichert and Dr. Bidgood belongs the credit for the discovery

that replantation of an entire limb may be possible when and even when the main artery and vein have been previously ligated. The story of the successful case is as follows: November 1, 1920, Dr. Reid replanted the left hind leg of a dog. Ten days later Dr. Reichert ligated the femoral artery and vein of the opposite (right) leg for the purpose of making X-ray studies of the anastomotic circulation. On June 6, 1921, 7 months thereafter, Dr. Bidgood and Dr. Reichert amputated through the right thigh of this dog—bone undivided, having forgotten that the main vessels of this leg had been previously tied. They were surprised therefore to find that these vessels had become converted into fibrous cords and naturally feared that the replanted leg would become gangrenous. Finding later that the leg would live, we regretted that the obliterated vessels had not been severed. Hence Dr. Reichert excised a portion of each of the fibrous cords and examined them microscopically. Not only had the lumina become obliterated but the strands consisted of nothing but white fibrous tissue, the muscle and elastic tissue of the coats having disappeared. Whatever may be the explanation of this successful replantation in one act, the result is remarkable—almost beyond belief. This experiment will of course be repeated, many times if necessary, and Dr. Reichert has made the preliminary ligation of the femoral artery and vein in a number of dogs with the intention of practising the amputation and replantation at various periods thereafter.

Surgeons can best comprehend the perfection of technique required for conducting such experiments. Were it not for the fact that well nourished tissues can take care of many organisms few wounds would heal by first intention. But in the replantation experiments unusual precautions have to be taken for the reason that a devitalized limb presumably has little power to resist infection. Of the two surfaces which we are asking to unite, one is for a time quite dead if all the structures have been divided. When the artery and vein have been left for secondary ligation little imperfections in technique need not be disastrous. The impossibility of having up to the present time an absolutely perfect technique may possibly account in part for the fact that the replantations have not succeeded when all the structures have been divided except in the one instance. It is, however, astonishing, I may say hardly believable, that the complete replantation should have been successful even after preliminary ligation of the artery and vein. Having once been accomplished, an occasional repetition of the success may safely be predicted. With a technique still further perfected we might find that without preliminary ligation of the main vessels a complete replantation is occasionally possible.

After 16 days and probably earlier the new lymphatics crossing the scar are demonstrable by injection. This is perhaps the most satisfactory functional proof we have of the regeneration of lymphatics.

On the 6th day the femoral artery and vein may, as stated above, be safely ligated. Hence on the 6th day or earlier the entire circulation of the leg is carried on through the newly formed vessels—lymphatic, venous, arterial.

On the 12th day the swelling, which increases during the first week after replantation, has about disappeared.***

* The complete paper with illustrations will be published elsewhere by Dr. F. L. Reichert.

** I was greatly pleased a few weeks ago to have my attention called by Sir Almroth Wright to the following paragraph in his paper entitled: "Introduction to Vaccine Therapy:" "Lastly—for it is impossible to mention all the points, streptococcic infection would appear to be responsible for that swelling of the arm so often seen after amputation of the breast—that swelling which finds, as we are told, a perfect explanation in the 'mechanical blocking of the lymphatics.' " (Nelson Loose Leaf Medicine, 1920.)

*** Lantern pictures illustrating the author's latest method of operating for cancer of the breast, of the dogs at various periods after the replantations and of skiagrams of the injected newly formed arteries were exhibited.

DEGENERATION AND REGENERATION OF THE LATERAL-LINE ORGANS IN *AMIURUS NEBULOSUS*

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If the nerve innervating the taste buds in the barbels of the catfish is cut, the taste buds degenerate (Olmsted, 1920b) in ten to fourteen days. Regeneration of the taste buds follows the regeneration of the nerve and is completed in about sixty days. The lateral-line organs are related anatomically to the lateral-line nerve much as the taste buds are to their nerve. Do lateral-line organs degenerate and regenerate as taste buds do?

The lateral branch of the vagus nerve innervating the lateral-line organs was severed in *Amiurus*. The sense organs are conspicuous structures and normally the sensory and supporting cells are easily distinguished. The first indications of degeneration appeared on the fourth day after the operation at which time the organs began to lose their distinct appearance. The sensory cells decreased in size and disappeared, first in the central part of the organ, where the nerve enters it, and later peripherally. Fragments of sensory cells may be detected for a few days longer, as degeneration in the single sense organ progresses. The supporting cells are more persistent, but by the end of two weeks the whole organ has usually disappeared.

Regeneration is more complicated than degeneration. If regeneration